CW RF System for the ATLAS Efficiency and Beam Intensity Upgrade

Speaker: Yong Luo, Physics Division, ANL

On Behalf of: **Sergey Sharamentov**, Peter Ostroumov, Gary Zinkann
Dan Paskvan, Albert Barcikowski, Mike Kelley

Eighth CW and High Average Power RF Workshop, May 13-16,2014
Trieste, Italy

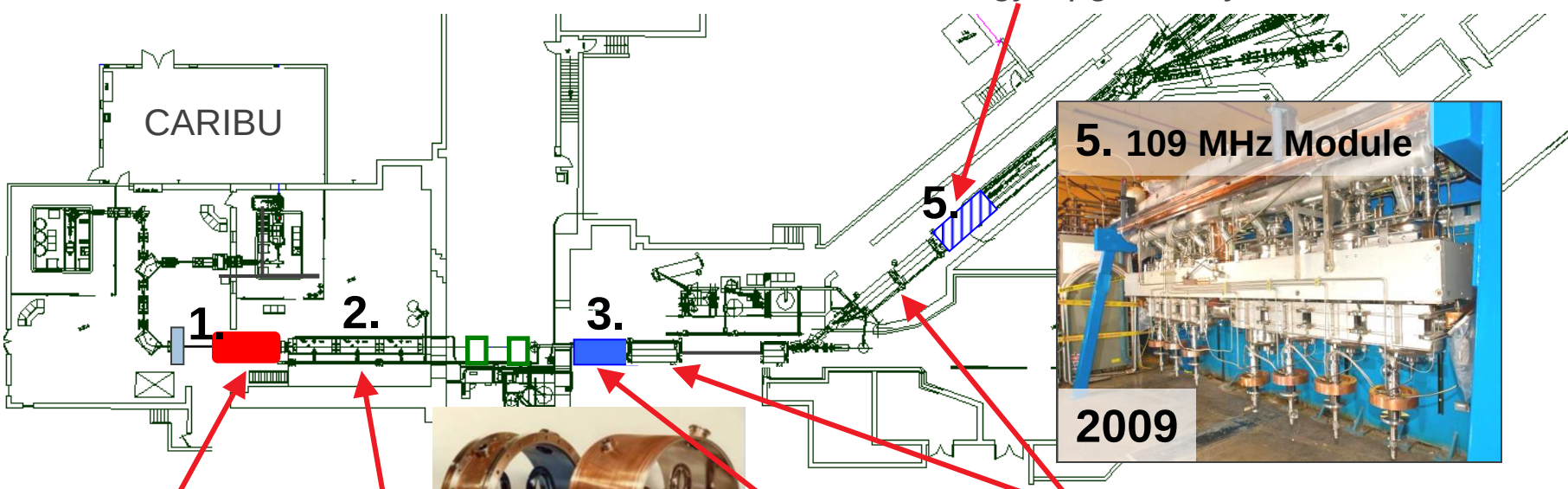
Content

- Introduction to ATLAS
- ATLAS Efficiency and Intensity Upgrade
- RF System for RFQ
- RF System for New Cryomodule Booster A
- Improvement
- Summary and Future Plan

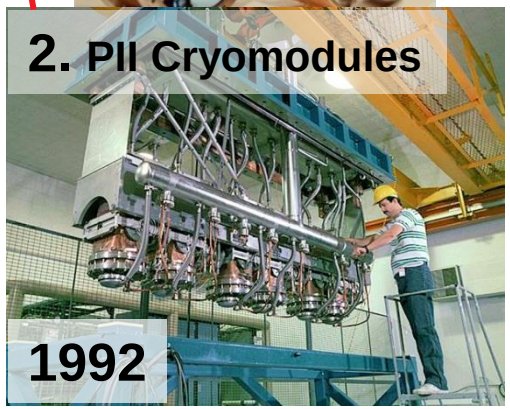
The Present ATLAS Accelerator Cryomodules

8 Cryomodules, 47 SC Accelerating Cavities

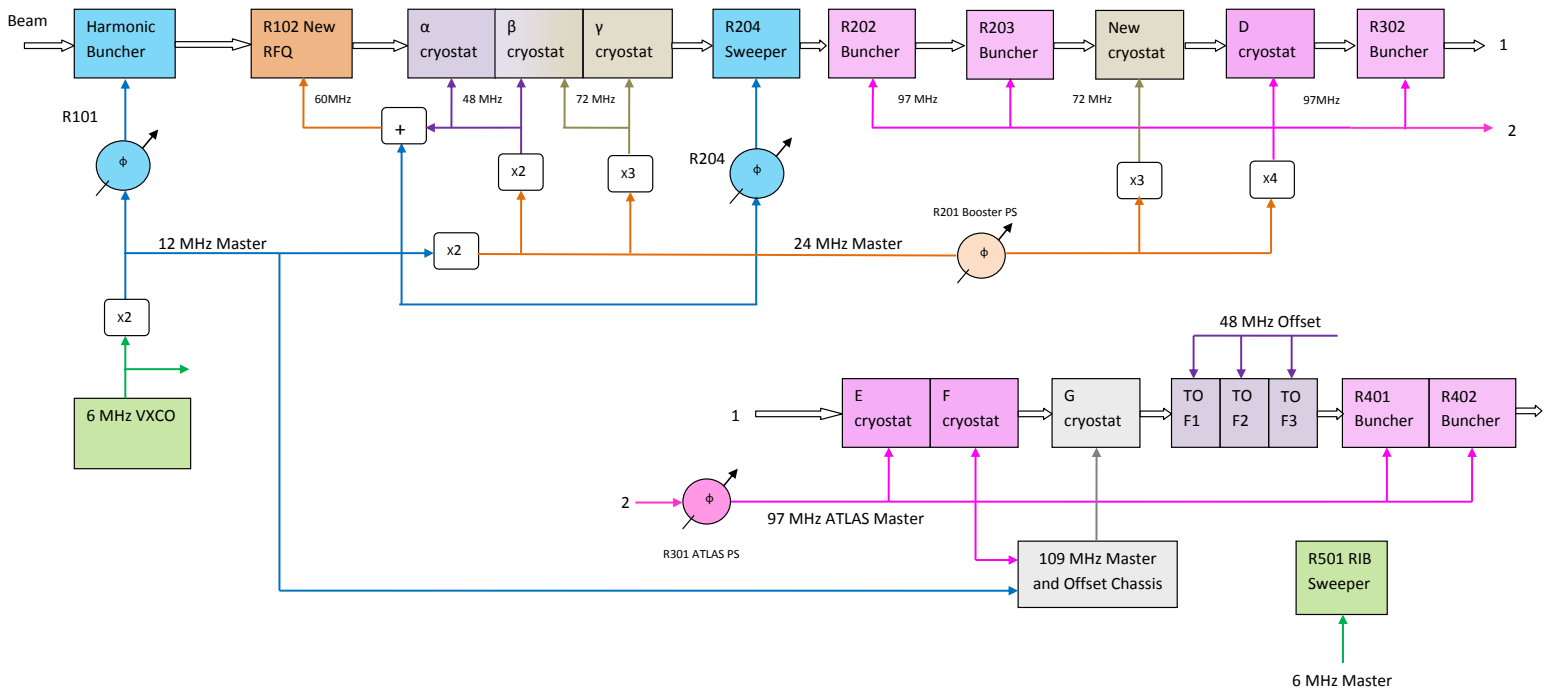
109 MHz Energy Upgrade cryomodule



4. Split-ring cryomodules



New ATLAS accelerator configuration

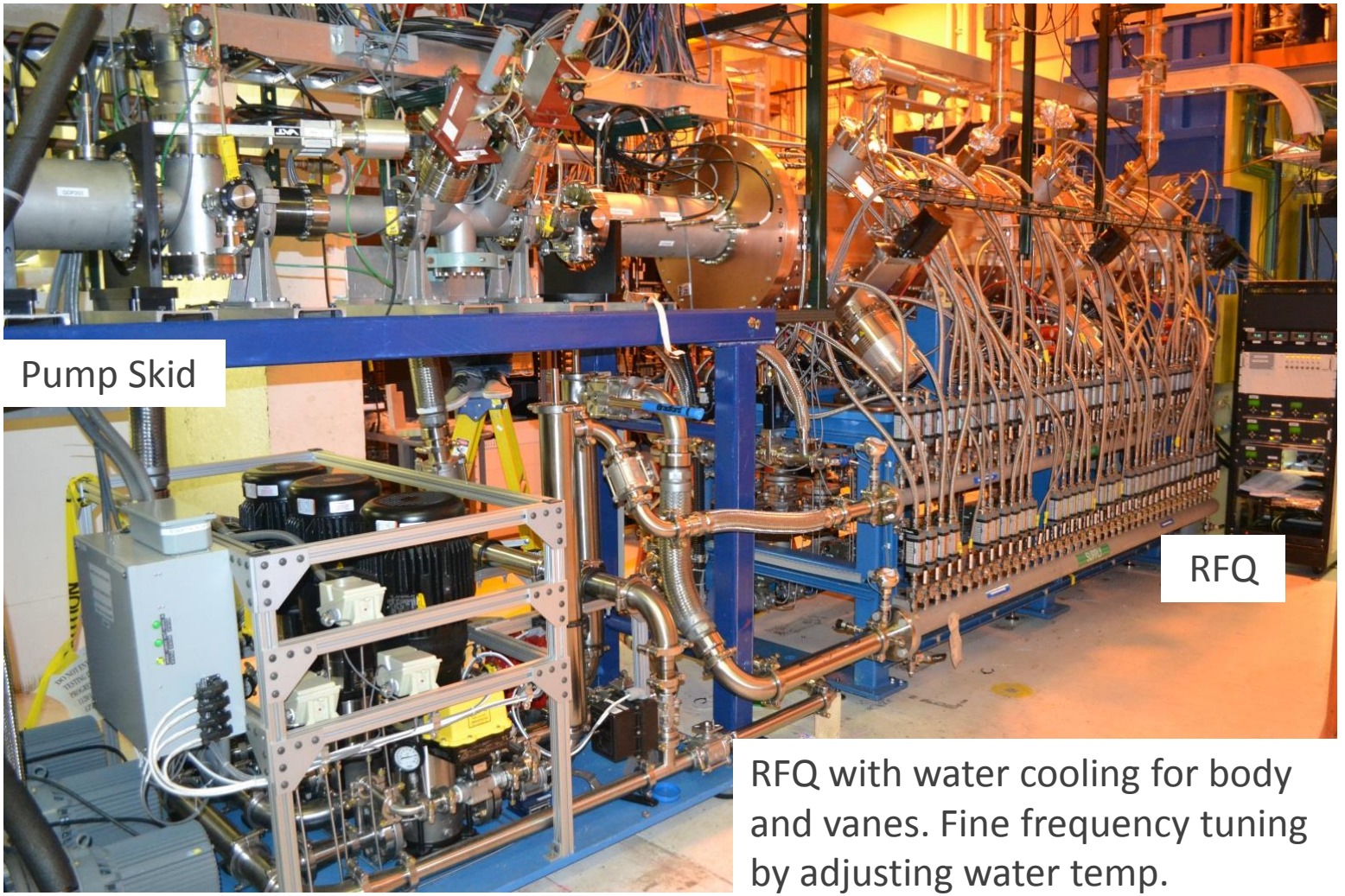


ATLAS Efficiency and Intensity Upgrade

- Increase beam transmission efficiency
  - Radioactive beams from CARIBU (from Proton to Uranium)
- Increase intensity of ion beams
  - Stable ion beams up to 10 pμA, hundreds of electrical microAmps
- This upgrade requires new RF system
  - Two 60 KW amplifiers for 60 MHz RFQ
  - Seven 4 KW amplifiers for New 72 MHz Cryomodule
  - New control system

60.625MHz RFQ and Water Pumps

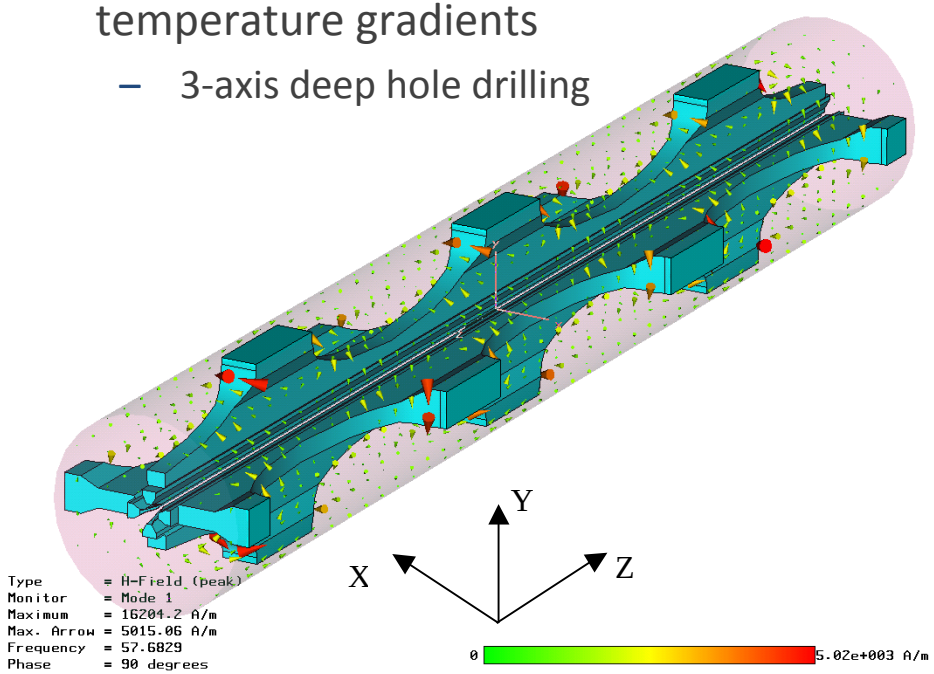
- Installed in 2012. In operation since January 2013



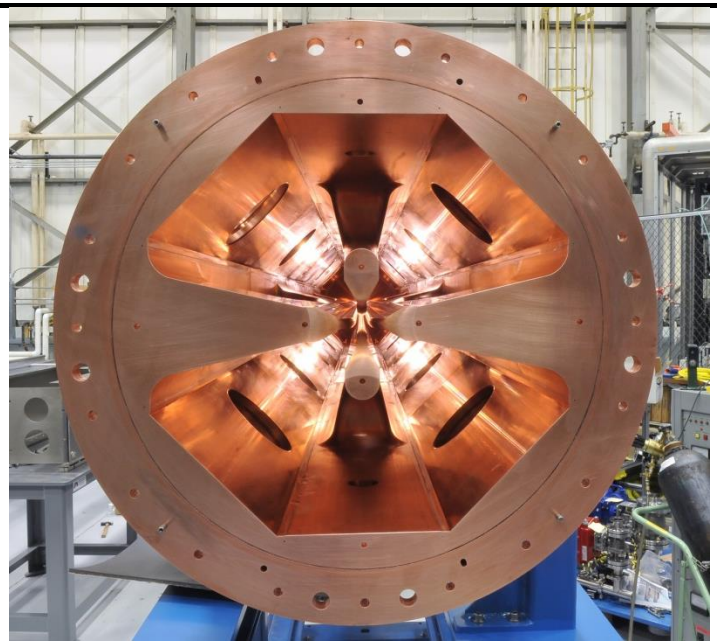
RFQ with water cooling for body and vanes. Fine frequency tuning by adjusting water temp.

ATLAS CW RFQ

- Total voltage is 2.1 MV
- Novel multi-segment split-coax structure
  - Internal size is 19” only for 60 MHz
  - Strongly coupled segments
  - Reduced number of tuners
  - Bead pull measurements are not required
- Cooling system is optimized to reduce temperature gradients
  - 3-axis deep hole drilling



	Parameter	Value
1	Duty cycle	100%
2	q/A	1/7 to 1
3	Input Energy	30 keV/u
4	Output Energy	295 keV/u
5	Average radius	7.2 mm
6	Vane Length	3.81 m
7	Inter-Vane Voltage	70 kV
8	RF power consumption	60 kW



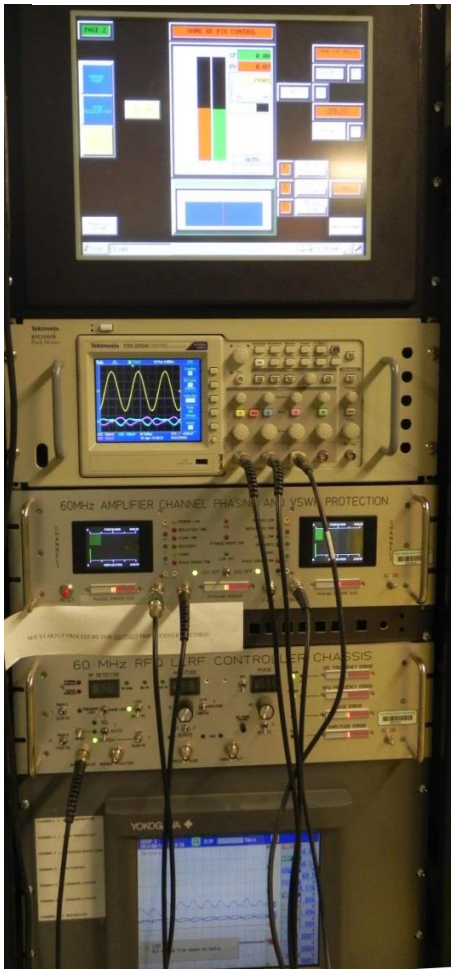
60KW Amplifiers to Provide Power for RFQ

3 1/8” Coax Line.

Two 60KW Amplifiers made by Amplifier Systems. Typically, both are used in operation. But with the adjustment of coupling ports, one amplifier can be used to provide power.

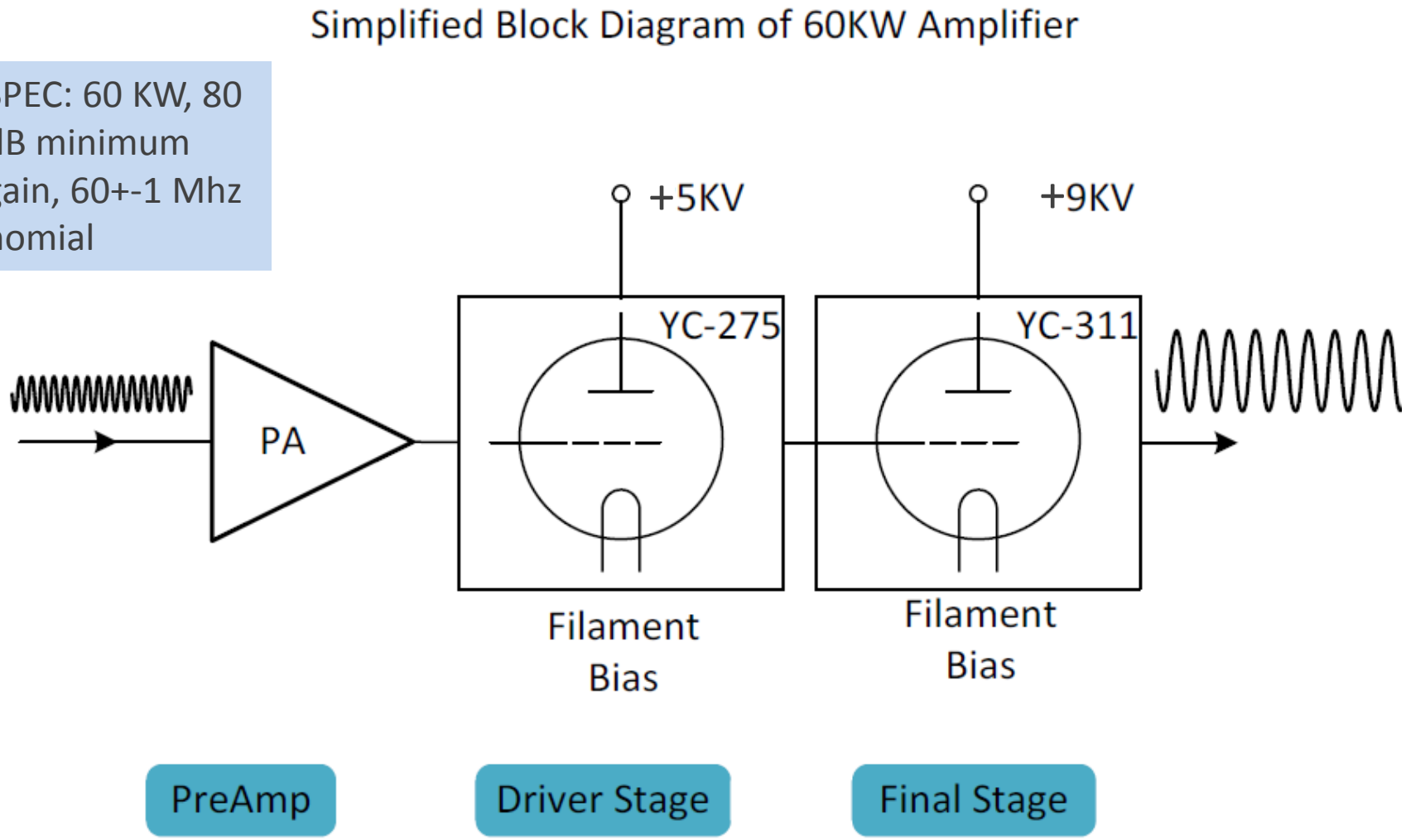
LLRF Contrl Units.

PLC Water CTRL GUI

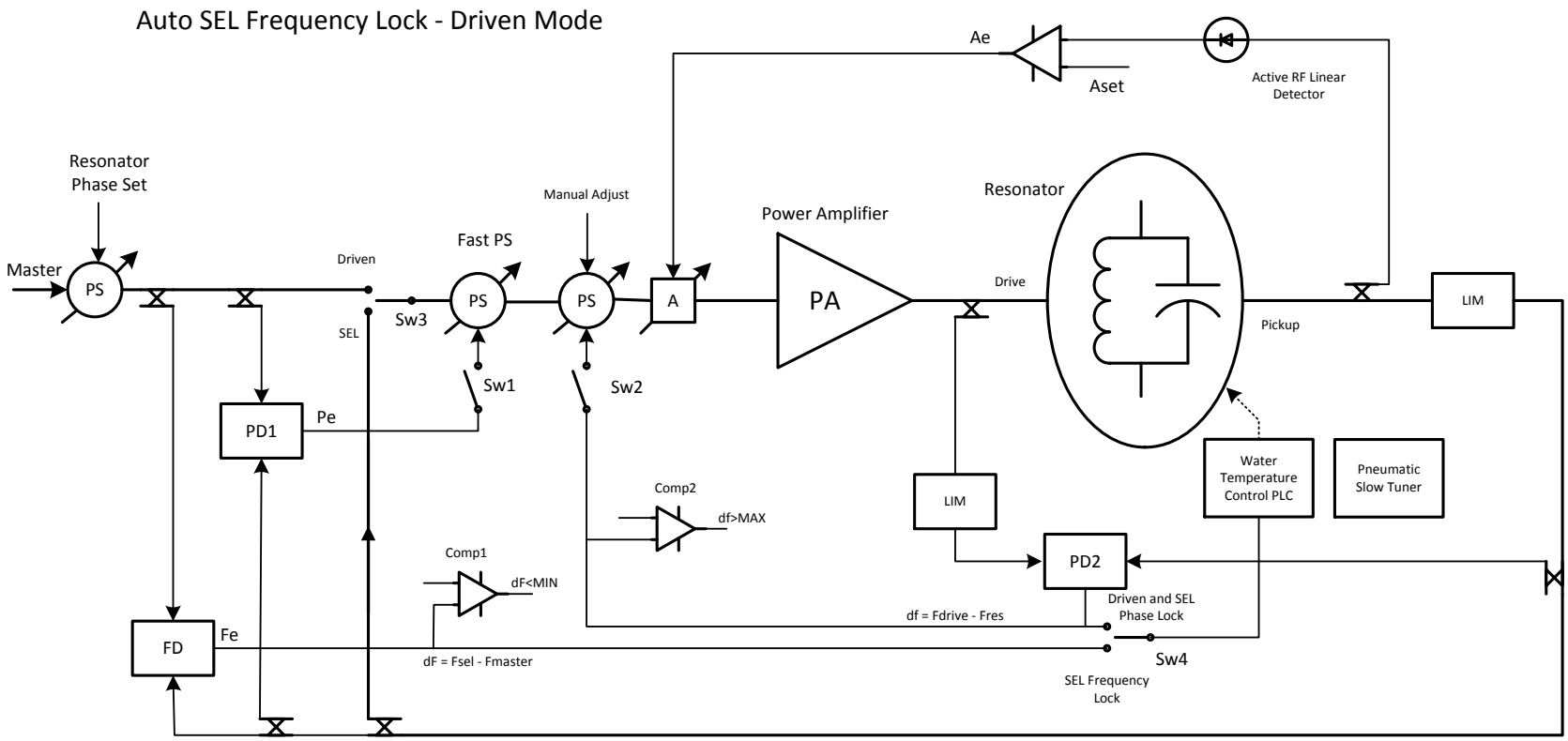


Simplified Block Diagram of 60KW Amplifier

SPEC: 60 KW, 80 dB minimum gain, 60+-1 Mhz nomial

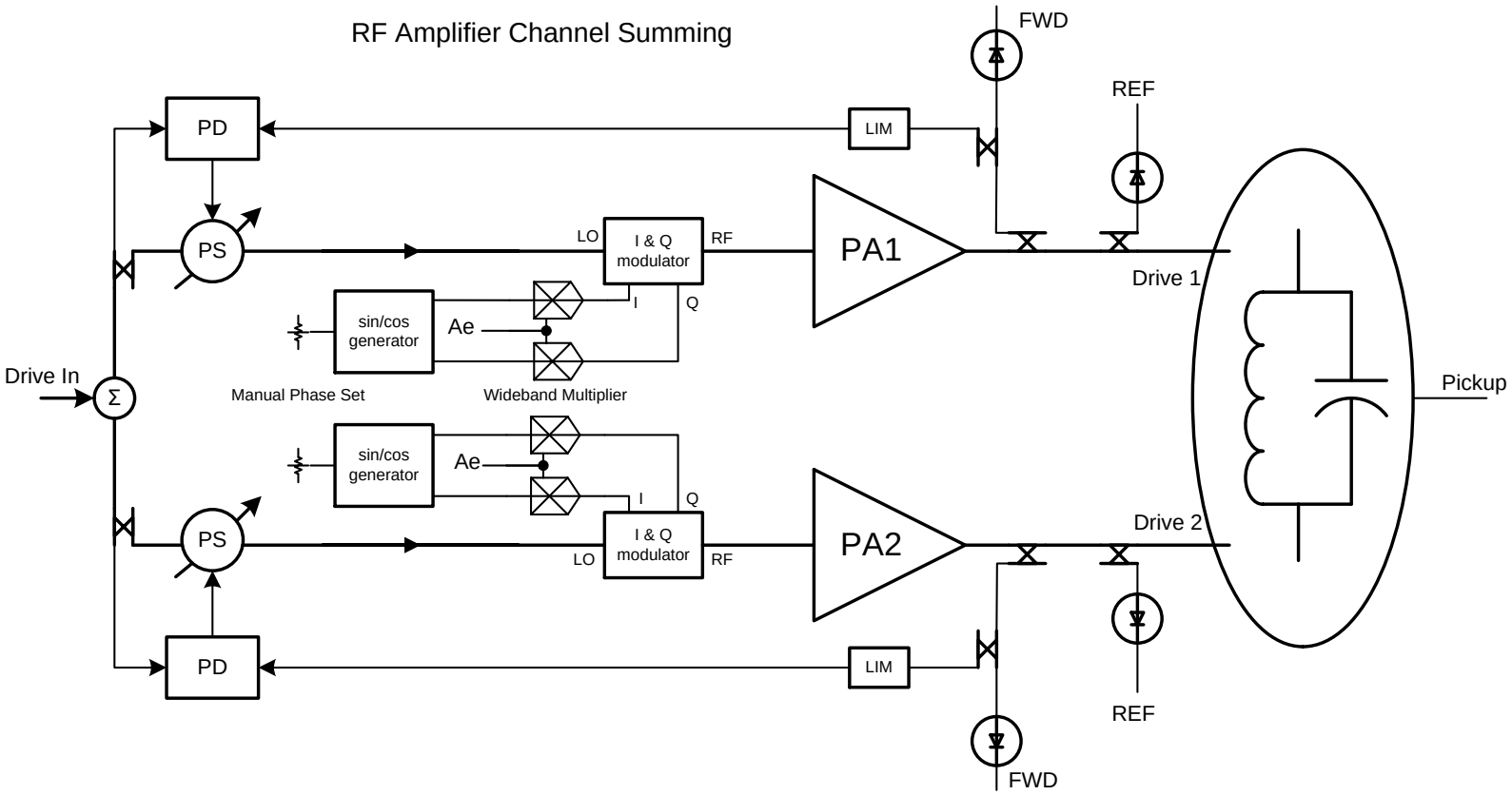


Automated SEL – Driven Mode System



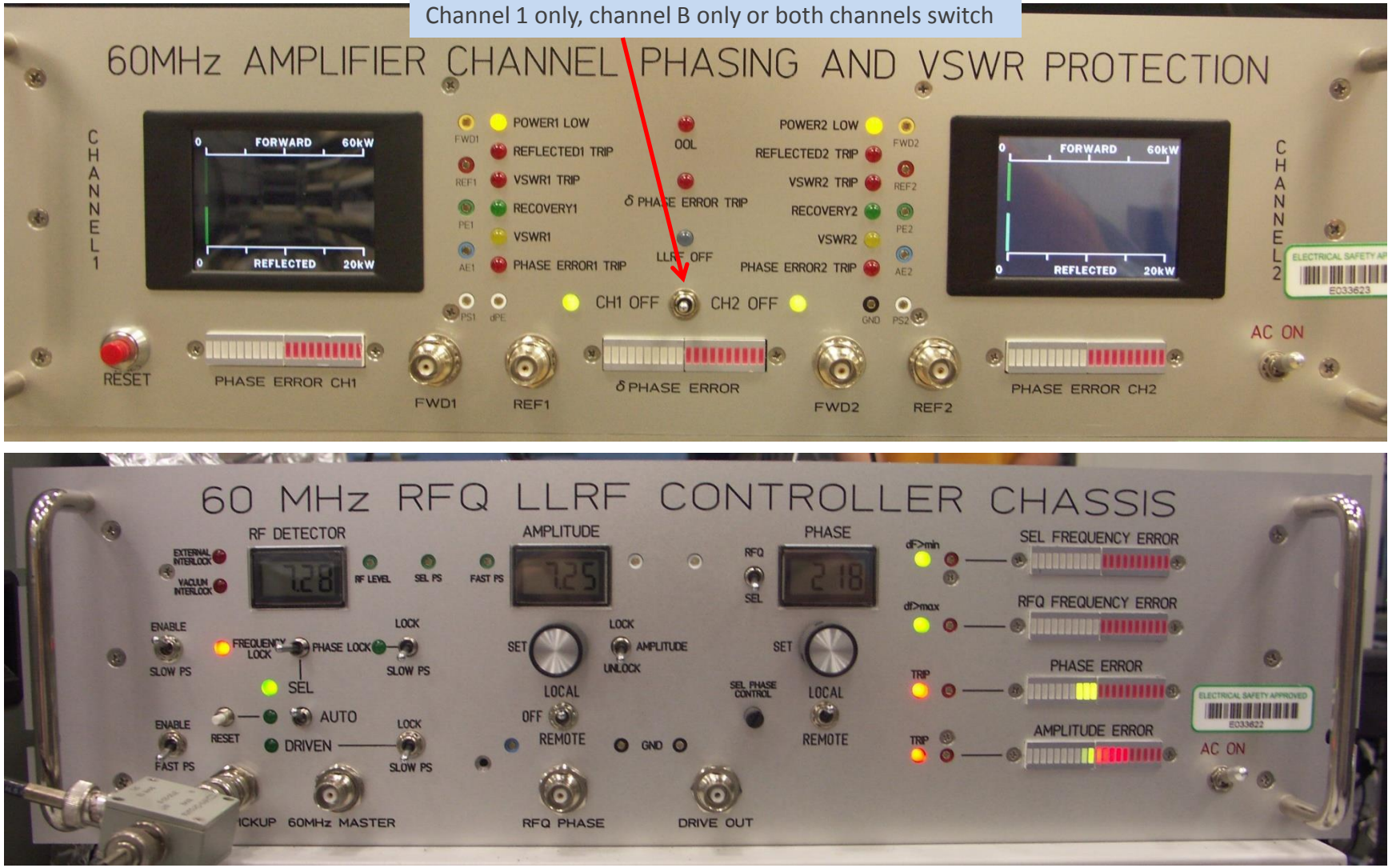
-allows for driven mode, SEL frequency and phase lock mode and Auto
-SEL frequency lock mode for RF power fill-in, driven for acceleration in Auto

Summing Two RF Amplifiers for ATLAS RFQ



-two individual phase stabilization loops
-I&Q modulator used as 360 degrees phase shifter and fast amplitude regulator

LLRF Control for ATLAS RFQ



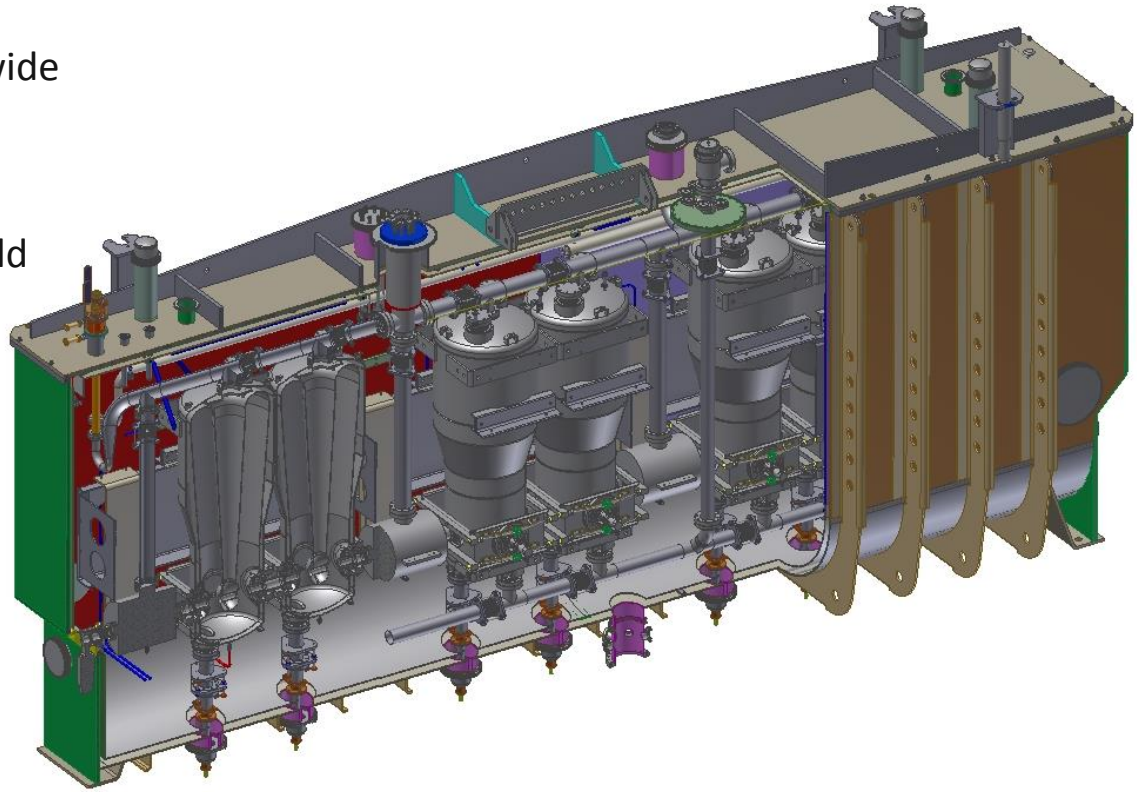
Cryomodule of 7 QWRs and 4 SC Solenoids

- Seven β = 0.077, 72.75 MHz quarter-wave cavities
- Four 9-Tesla superconducting solenoids
- Replaces 3 old cryomodules with split-ring cavities
- Total design voltage is 17.5 MV, 4.5K cryogenic load is 70 W
- Will be operated to provide ~20 MV, 4.5K cryogenic load is 85 W

5.2 m long x 2.9 m high x 1.1 m wide

Vacuum Vessel
Room Temperature Magnetic Shield
Aluminum Heat Shield
(MLI not shown)

Compact design, focusing period
Includes 2 cavities and 1 solenoid



Summary of Performance for New Cryomodules

	New	G-Tank	
	Beta=0.077	**Beta=0.15**	**Comment**
Number of Cavities	7	7	
Number of Solenoids	4	1	
Operating Temperature	4.5 K	4.5 K	
Voltage per Cavity in Cryomodule	>2.5 (4.1) MV	>2.0 (3.0) MV	Cavity limit in parentheses
Performance Limiting System	?	VCX fast tuner	
E_{PEAK} in Cryomodule	40 (70) MV/m	26 (39) MV/m	Cavity limit in parentheses
B_{PEAK} in Cryomodule	57 (100) mT	47 (69) mT	Cavity limit in parentheses
Power to Helium/Cavity	5 W @2.5 MV	8 W @ 2 MV	

Stored Energy @1MV/m of the new Cryomodule: 0.15 J

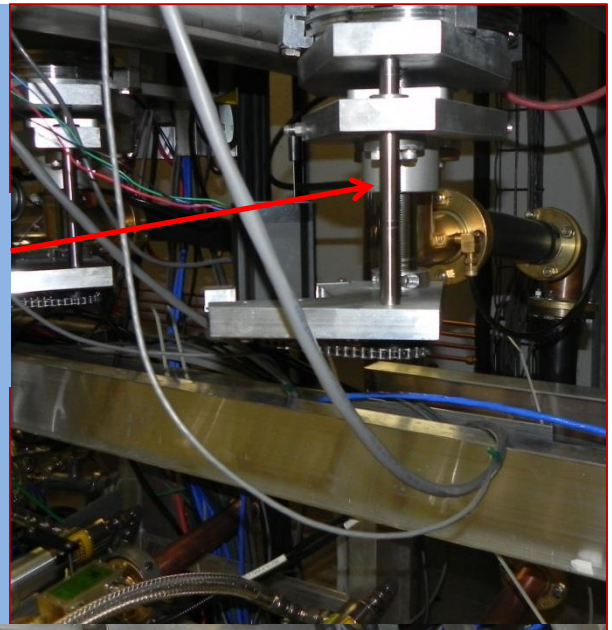
New 72.75 MHz Booster A SC Cryomodule

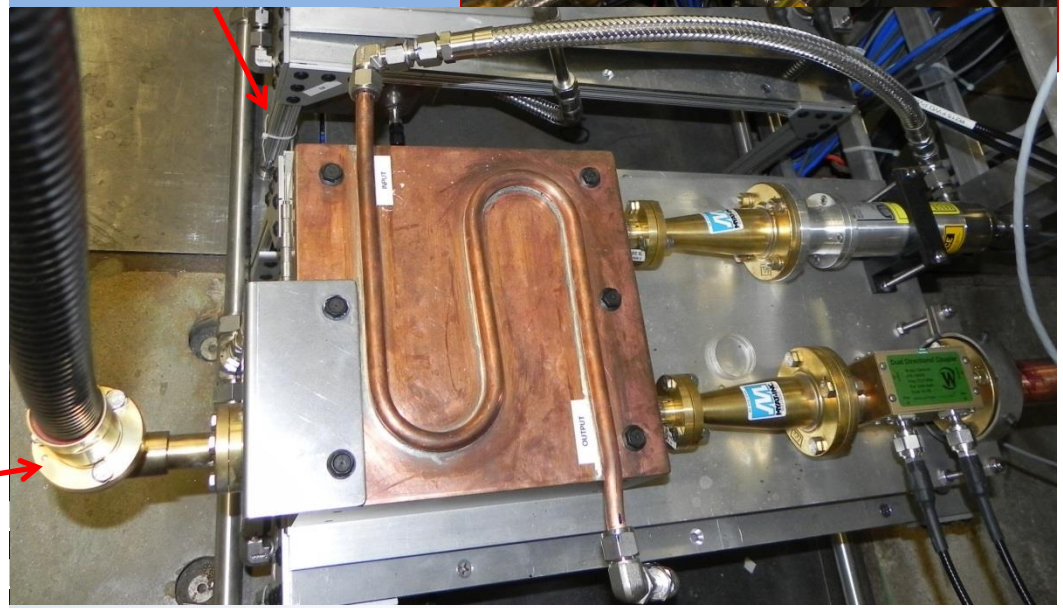
5.2 m long x 2.9 m high x 1.1 m wide

Left:
Cryomodule A

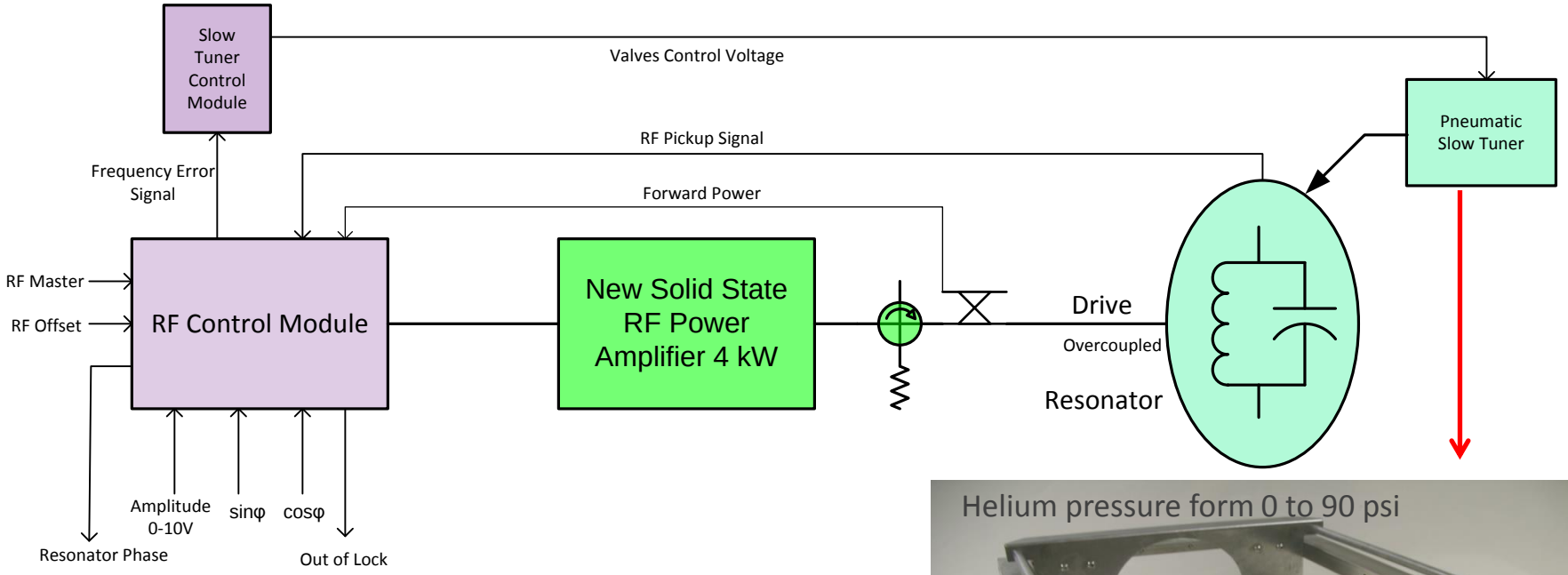
Right Upper: RF Coupling Port

Right Bottom: Circulator and Dummy Load with Water Cooling.

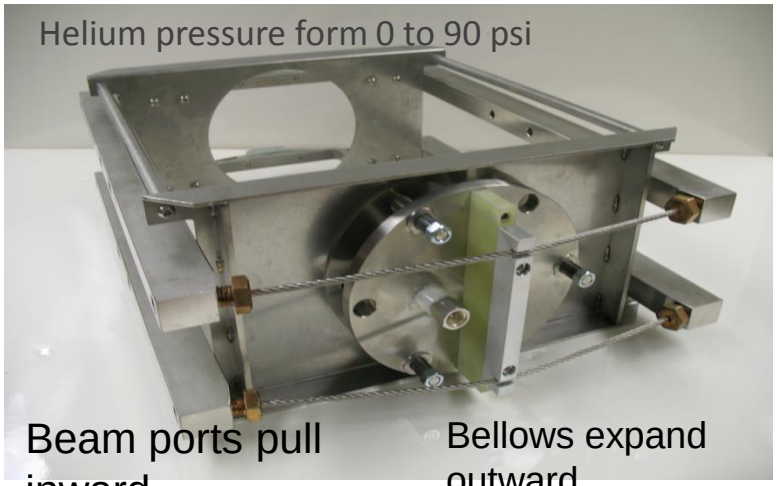




New 72.75 MHz Resonator RF System



Control System

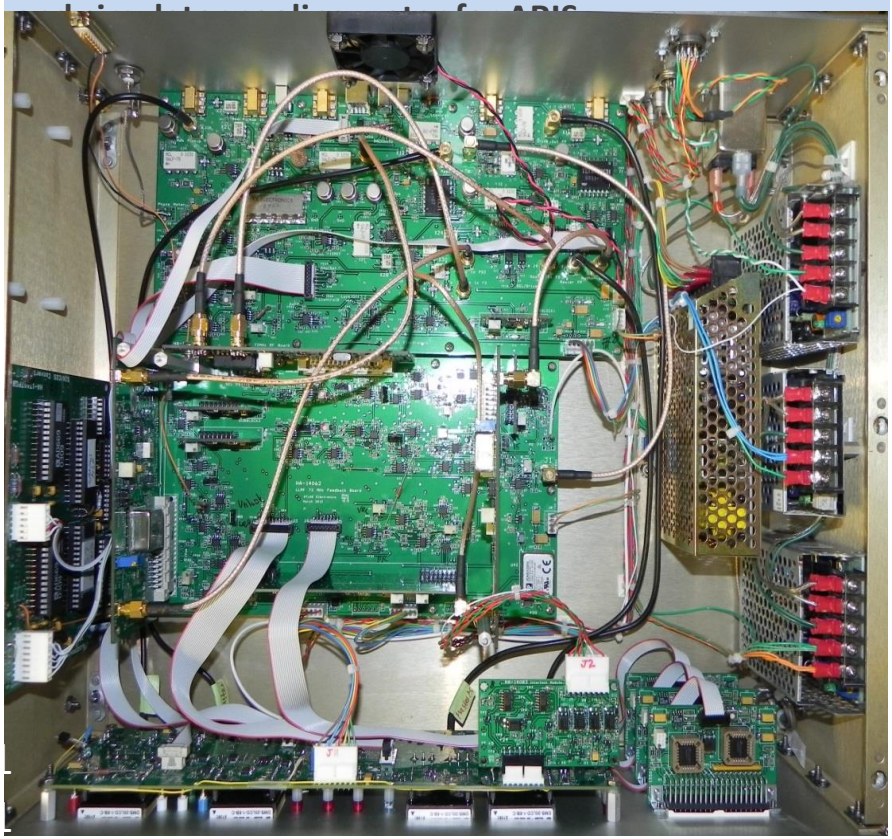


- Over-coupling is a main feature for phase lock
- Transmission through the Cryomodule is almost 100%

Power Supply, Amplifier and LLRF Control Unit

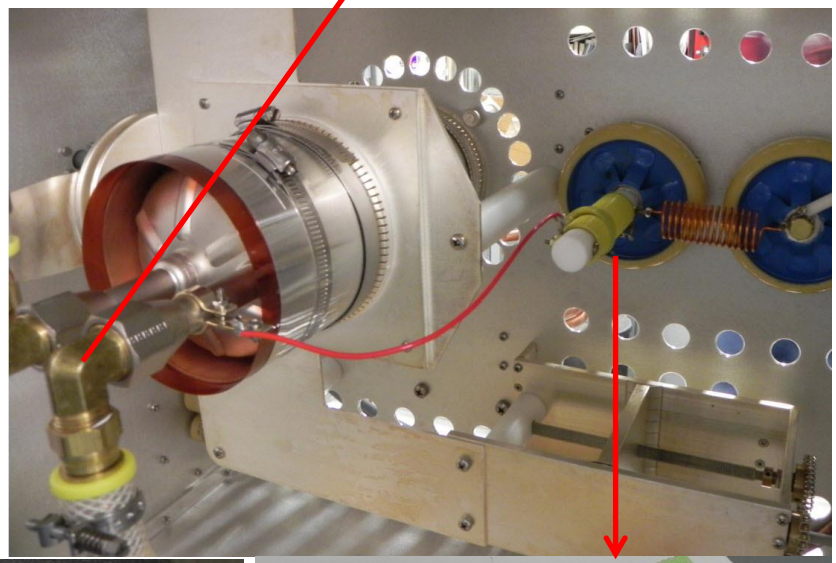
Model: TOMCO BT4K-Alpha
SPEC: 4 KW, 3 Phase AC 208V, 72.75+-1 Mhz nomial. Use LDMOS

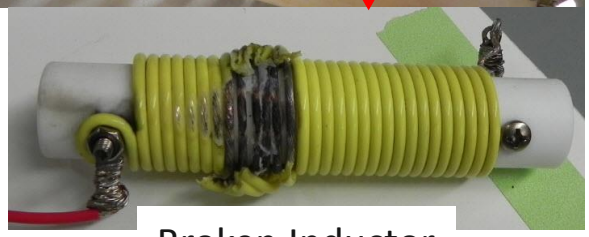
- Slow Tuner control is integrated into LLRF controller
- Contains two phase detectors, frequency detector, three phase shifters and two RF limiters
- Provides regulation of resonator phase and amplitude
- **Provides RF power interlock resonator temperature**



Improvement on Reliability of 60KW Amplifiers

- Deionized (DI) Water causes corrosion of Brass fittings
  - *Net chemical reactions:*
    - $Cu + H_2O \rightarrow CuO + 2\ H_{ads}$ (or $Cu_2O + 2\ H_{ads}$)
    - $2\ H_{ads} \rightarrow H_2$
    - $H_2 + ½\ O_2 \rightarrow H_2O$
  - Replaced most brass fittings with stainless steel fittings (especially connected with H.V.)
- Other
  - New home made inductor w/different value (removing unwanted resonance)
  - New powerful fans
  - Better insulator for output capacitors: better isolation
  - Fuses (-> fast blow type)
  - PID loop parameters optimization
  - Others (example)





Broken Inductor

Summary

- New RF system is built and it meets the requirement
- New RF system runs smoothly with the improvement mentioned above

Future Plan:

- Installation of 60KW circulators
- Clean room environment for RFQ amplifiers
- Continuous improvement on other electronics
- For Tomco 4KW amplifiers, finishing stainless steel fittings replacement

End

Backup Slides